NMR spin echo excitation and detection of vortex lattice oscillations in a high temperature superconductor

W. Gilbert Clark, UCLA, Grant DMR-0334869

One of the most important aspects of understanding High Temperature Superconductors is to measure the detailed properties of the vortex structure that forms when a high magnetic field is applied. We have recently found a new way to measure these properties. It is the oscillation of an NMR spin echo when its arrival time is varied, as shown on the figure. It corresponds an oscillation of the vortex lattice itself. Analysis of such measurements provides the frequency of the oscillation, which is important for understanding the fundamental properties of the vortex lattice.

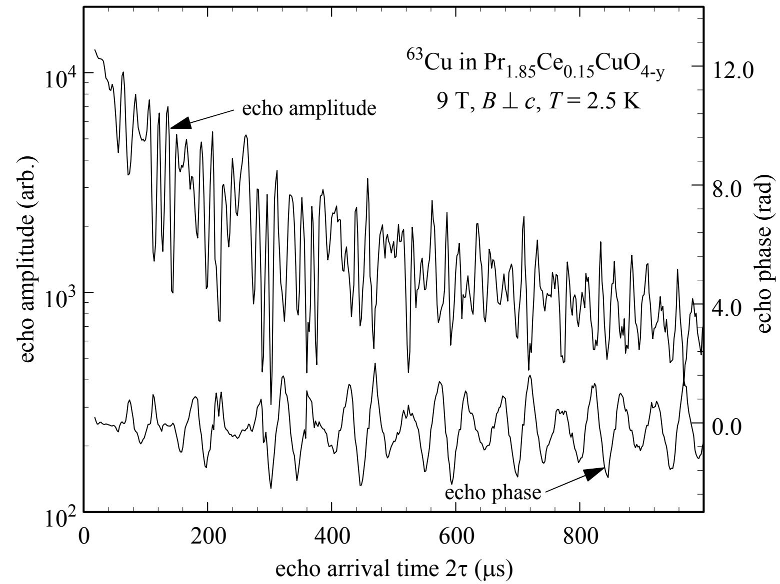

Figure - Decay of the amplitude (upper) and phase (lower) of the NMR spin echo. These large modulations, which we believe have not been reported before, are attributed to oscillations of the vortex lattice in the superconductor.

When a moderate or high magnetic field is applied to a high temperature superconductor, it penetrates in a regular structure called the vortex lattice. Each unit of this lattice contains one quantum of magnetic flux. The vortex at the center of each element of the vortex lattice corresponds to a circular electrical current, which creates a spatial variation of the magnetic field in the sample. The vortex lattice is usually pinned to the sample structure by defects, so it is not free to move. (This pinning is very important for the technical applications of superconductors). When the vortices are pinned, the structure is somewhat analogous to the musical string in a piano. If something "hits" the vortex, it can "ring" like the string on a piano. Our interpretation of the new result described here is that the radio frequency pulses used to generate the NMR spin echo "hit" the vortex and set it to ringing. This ringing then creates a variation in the magnetic field in the sample which causes the spin echo to oscillate in time, as seen in the figure. There, the lower curve measures the amplitude of this oscillation of the vortex lattice with time. In this measurement, a frequency of 20,000 cycles per second is observed. From such measurements, it is hoped to obtain a much better understanding of the inertial properties of the vortex lattice, which can then be used to evaluate the corresponding theoretical models.

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Educational impact

Resources from this grant are used to train three graduate students, one postdoc, and one undergraduate student, who has participated in our research group under the NSF REU program.

Broader impact

An important aspect of the work supported by this grant is that it includes substantial collaborations with groups at: The University of Maryland, the National High Magnetic Field Laboratory (USA), the Grenoble High Magnetic Field Laboratory (France), and the Indian Institute of Science, Bangalore. Also, advanced, laboratory-built instrumentation for carrying out these measurements is provided to some of these groups. This project is also a close collaboration with Prof. S.E. Brown's group at UCLA (Grant: DMR-0203806).